

Co-firing in coal power plants and its impact on biomass feedstock availability

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Legislation Affecting Biomass Production in the U.S.

Federal legislation to address greenhouse gas emissions in the United States

- 2005 Energy Bill
 - Renewable Fuel Standard (RFS)
 - Increasing amount of cellulosic biofuel in gasoline
- Proposals for a U.S. cap-and-trade system
 - American Clean Energy and Security Act of 2009
 - American Power Act of 2010

State legislation

- Renewable Portfolio Standards (RPS) in 29 U.S. states
 - E.g., 25% of renewable energy in Minnesota by 2025
 - Biomass as part of the renewable options in all states

Biomass Demand and Agriculture

Two demand sources for biomass:

- ① Biofuel plants (corn and cellulosic)
- ② Electric power plants
 - Dedicated power plants
 - Co-firing power plants

Research questions:

- What is the potential for spatial competition among biomass users?
- What is the effect of co-firing existing coal power plants with biomass on agriculture?

Influence of federal and state policy on lignocellulosic biomass such as agricultural residues, energy crops, and forest residues

Biomass Co-firing

Advantage of co-firing

- (Almost) ready to use for co-firing
- Lower greenhouse gas emissions when compared to biofuels
- Existing infrastructure and location

Co-firing coal power plants

- Relatively easy retrofitting of existing coal-fired power plants
- Small and low cost modification to existing power plants

Biomass feedstock:

- Crop residues
- Energy crop
- Forest residues

Competition of power plants for limited biomass resources

Power Plant Location

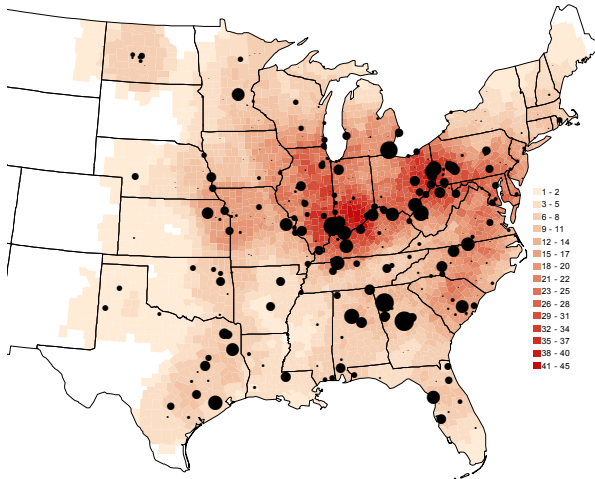


Figure: Number of power plants within 200 km of county's centroid

Literature Review

Energy Information Administration (EIA): 25% RFS (sales) and 25% RPS by 2025

- Rise of biomass consumption from 30 million tons to 571 million tons (2007-2030)
- Price increase of biomass from \$30 to \$88 per ton

Biomass analysis in the context of lignocellulosic ethanol production or co-firing

- Biomass availability for ethanol (Mabee et al. 2011)
- Transportation cost analysis for parts of Michigan (Egbendewe-Mondzozo et al., 2011) or Spain (Panichelli and Gnansounou, 2008)
- Co-firing and transportation in Illinois (Khanna et al., 2011)

Co-firing forest residue

Model Components

Agricultural sector

- Field crops: corn, soybean, and wheat
- Energy crop: switchgrass
- County-level allocation of cropland given prices

Electricity sector

- 398 Coal-fired power plants

Transportation cost

- Availability of all biomass at the centroid of the county
- Cheapest biomass based on distance and available quantity \Rightarrow Lowest marginal cost

Forest sector

Agricultural Sector

Calibration of demand and net revenue functions:

- Corn, soybeans, and wheat
- Four demand sectors: food/domestic, feed, exports, and biofuel
- Cost by region from the USDA/ERS Commodity Costs and Returns

Expectations are rational in the sense that:

- Price taking behavior of all landowners
- Area allocation matches expectations about aggregate production and prices

Profit maximization for field crops

$$B_i^f(a) = \sum_j p_j \left(a_{ij}^f + a_{ij}^b \right) y_{ij} + \alpha_{ij} \left(a_{ij}^f + a_{ij}^b \right) + \frac{1}{2} \beta_{ij} \left(a_{ij}^f + a_{ij}^b \right)^2$$

Profit maximization for biomass crops

$$B^b(a) = p_{bm} \sum \delta_{ij} y_{ij} a_{ij}^b - \eta_{ij} a_{ij}^b$$

Electricity Sector

Data on 398 coal fired power plants (2010 Energy Information Administration)

- Type of coal (i.e., anthracite, bituminous, lignite, sub-bituminous)
- Sectors: electric utilities, independent power producers (IPP), and independent power producers with combined heat and power (IPP CHP)
- All North American Electric Reliability Corporation (NERC) regions except Western part of the country (i.e., WECC)

Assumptions:

- No investment decision of co-firing
- Unaffected heat input of the power plant
- Uniform boiler efficiency of 88% and 8000h of yearly operation

Scenarios

Table: Summary of key scenario parameters

Scenario	RPS	p_{bm}	Switchgrass Cost
RPS 15: Low Incentive	15%	\$3	High
RPS 15: High Incentive	15%	\$4	Low
RPS 25: Low Incentive	25%	\$3	High
RPS 25: High Incentive	25%	\$4	Low

Simulation Procedure

Exogenous variables:

- Price of biomass
- RPS requirement

Simulation steps:

- 1 Set p_{bm} and RPS
- 2 Land allocation by the farmer and production of agricultural residues and/or switchgrass
- 3 Demand of coal-fired powerplants to individual counties based on transportation cost and biomass price
- 4 Calculate excess supply and demand of biomass

RPS 15: Low Incentive

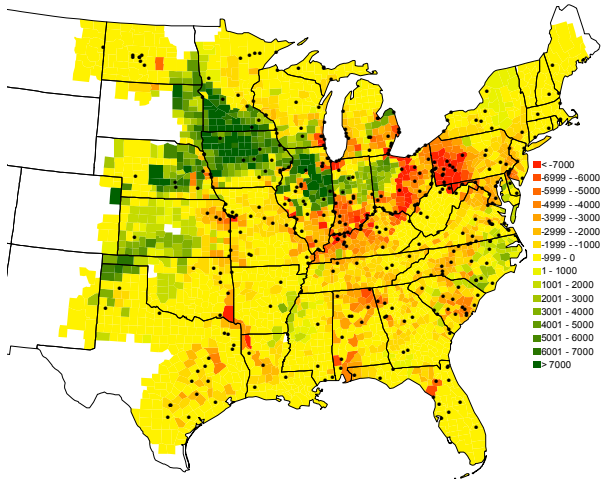


Figure: RPS = 15%, p_{bm} = \$3, High Switchgrass Production Cost

RPS 15: High Incentive

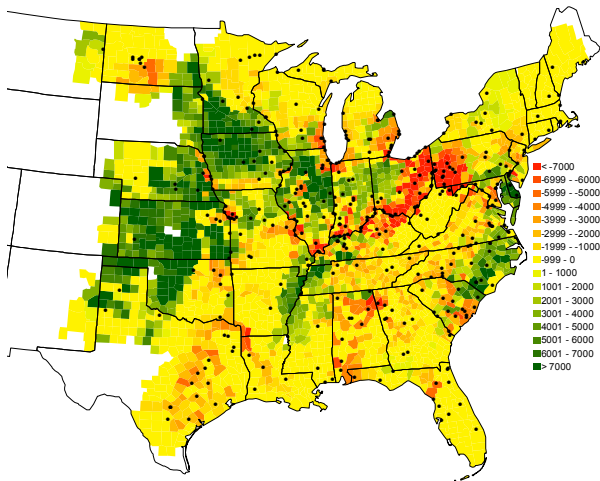


Figure: RPS = 15%, p_{bm} = \$4, Low Switchgrass Production Cost

RPS 25: Low Incentive

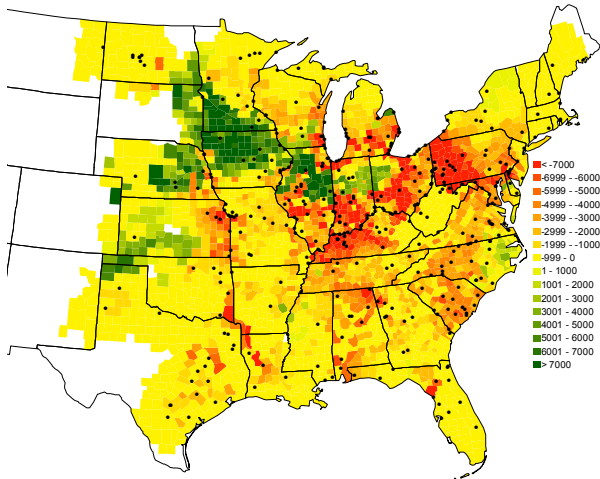


Figure: RPS = 25%, p_{bm} = \$3, High Switchgrass Production Cost

RPS 25: High Incentive

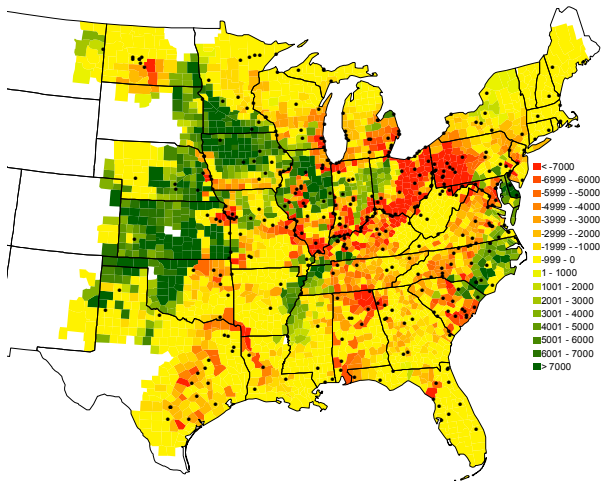


Figure: RPS = 25%, p_{bm} = \$4, Low Switchgrass Production Cost

Conclusion

Political perspective

- Legislation leading to the potential use of biomass for co-firing purposes due to state renewable portfolio standards

Coal-fired power plant perspective

- Possibility to mitigate greenhouse gas emissions by co-firing with biomass

Agricultural sector

- Possibility of additional revenue from selling to the power plant

Competition of power plants for limited supply of biomass